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| USNOL ltr, 29 Aug 1974 ; USNOL ltr, 29 Aug 1974 |

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From:  R. H. /Stresau, Jr.
       L. E. /Starr, Jr.

To:    N.O.L. Files

Via:   Chief, Explosives Research Department

Abst: A series of measurements was done of the
conditions for propagation of detonation between
confined charges in the size range of fuze explosive
train components. The point at which propagation
across a gap or other relative displacement should
occur for fifty percent of trials was determined by
varying the displacement in accordance with the so-
called Bruceton up and down method. Critical axial
air gaps were determined as functions of column diameter,
density, explosive material, and column length and criti-
cal transverse displacement was measured as a function
of explosive material. Axial gap, as might be expected,
varies directly with donor diameter. For any given
donor diameter there is, apparently, an optimum acceptor
diameter which is slightly smaller than the donor diame-
ter. The gap also increases with donor column length,
but a given increase in quantity of explosive is more
effective when added by increasing the diameter than by
increasing the length. The sensitivity of various
explosives as indicated by the gap across which they can
be  initiated shows a reasonably good agreement with
impact and minimum priming charge sensitivities of the
same explosives. The critical gap is related directly
to donor density, in general, and inversely to acceptor
density, but the effect of acceptor density is much
greater. The critical transverse displacement for
propagation between various explosives shows a similar
pattern to the axial gap but the relationship is not
linear because the more sensitive materials are initiated
by shock transmitted through the metal while the less
sensitive materials require an overlap of the two
columns, so that two different mechanism are involved.

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The above observations apply to the explosive materials, confinements, charge dimensions, and densities used in these experiments. Extreme caution is recommended in their application to other conditions.

Fwrd: The data and conclusions presented here are not the final judgment of the Explosives Research Department or this specific project. Additional reports will be made as the data becomes available.

Ref: (a) Ordnance Board Investigation No. 808 "The Propagation of a Detonation Wave through Explosive Trains in Fuzes", C. Dodd (S-6300)

(b) OSRD Report #4040 "Statistical Analysis for a New Procedure in Sensitivity Experiments", Applied Mathematics Panel, National Defense Research Committee (S-5892)

(c) NOLM 8696 "A Method for the Fabrication of Low Energy Electric Initiators"

(d) NOLM 10336 "The Sensitivity of High Explosives to Pure Shocks".

(e) NOLM 10765 "Density of a Pressed Explosive as a Function of Loading Pressure"

(f) NavOrd Report #87-46 "Table of Military High Explosives" Hercules Powder Co. (S-10982)

(g) NavOrd Report #57-46 "The Stability of Detonation" H. Eyring et al.

Encl: (1) Plates 1 through 18.

INTRODUCTION

1. Although successful explosive trains have been designed and built for years, many of the principles which should govern such designs are imperfectly understood.

2. One field in which quantitative information is particularly lacking is that of the propagation of detonation between small confined charges such as detonators and leads. Failure at this point has resulted in more than one serious delay late in the development of an urgently needed ordnance item. The cost of such delays in war time cannot be reckoned. Most experimental work in this field has been tests of specific items. Where failure occurred several changes were frequently made simultaneously so that it became virtually impossible to ascertain the relative importance of the changes to any improvement which may have resulted. Thus, although the designer gradually acquired a "feel" for the art, he was usually unable to state any rules which he followed. Among exceptions to this general rule is the work of C. Dodd, reference (a), who made systematic investigation of an explosive system. His experiments were comprehensive enough to yield information of quite general usefulness.

3.   With the object of broadening the scope of generally applicable data in this field, a series of measurements has been undertaken of the "critical" conditions for the transmission of detonation between small charges.  Although some thousands of firings have been made in obtaining the data recorded herein, the effects of many important variables have not been investigated and many of the mean values quoted may have been obtained with samples which were smaller than might have been desired.  It is hoped that the data will be useful to the designer.  It is believed that the derivation of a few qualitative relationships is justified.  The formulation of various mathematical relationships will have to wait for more complete data.

EXPERIMENTAL PROCEDURE AND APPARATUS.

## General

4.   The object of the experiments discussed herein is to determine the "critical" relative positions for the initiation of detonation in one explosive element (The "acceptor") by means of another (The "donor").  (See Plate 1.)  The "critical" position is defined as the most remote of a series of related points at which the donor will initiate detonation of the acceptor.  Such information, unfortunately, cannot be obtained for any one combination of a donor and an acceptor.  All that can be learned from one shot is that the acceptor was or was not initiated.  The first experiment which suggests itself is that of "working up" to the critical point from each side with a series of straddling shots using identical donors and acceptors.  However, it is impractical if not impossible to make components which are nearly enough identical for this type of experiments.  Thus, each set of donor and acceptor has a unique critical point.  The experiment must be directed toward determining the  average critical point which, upon a little reflection, can be seen to be the point at which fifty percent of the acceptors fire.  During the past war a method (reference (b)) for determining such statistics was devised by the Explosives Research Laboratory at Bruceton, Pa. and was analyzed and refined by the Applied Mathematics Panel at Princeton.  This method, which will be referred to herein as the "Bruceton Method", involves a series of trials the conditions for each of which is determined by the result of the previous trial.

The Bruceton Method

5.   The Bruceton Method (reference (b)), was originally devised for use in impact sensitivity work with drop test machines, but is applicable to a variety of other similar experiments.  As applied to the axial gap tests the method is as follows:  A series of gaps are chosen such that the differences between the logarithms of each pair of successive gaps

are equal. A donor and acceptor are located so that their
axes coincide and the distance between their closest faces
is equal to one of the chosen gaps (Plate 1). The donor
is fired. If the accepotr detonates, the next trial is made
using the next larger gap, and if it fails, the next trial
is made using the next smaller gap. This is repeated for
successive trials until the desired number of trials have
been made. The results, which are recorded as shown on the
sample record (Plate 2), may be analyzed by procedures
outlined in reference (b) to obtain an estimate of the mean
(fifty percent point) and standard deviation.

6. Although reference (b) suggests 100 shots as a reasonable
sample size, the tests discussed herein were generally limited
to samples sizes of 15 to 50 shots because of the considerable
expense and effort involved in the preparation of specimens.
This results in a loss of accuracy in the estimate but it is
compensated to some extent by the rather small deviations
observed in these experiments compared with most impact
sensitivity data.

## Criteria of Detonation

7. The Bruceton Method is applicable only where the result
of a single trial can be definitely placed in one of two
categories, in the case of propagation tests detonation or
failure of the acceptor. In general this can quite easily
be accomplished by direct visual observation of the deforma-
tion of the acceptor container. In the usual experiment, how-
ever, a few acceptors are found in which the deformation is
quite appreciable yet noticeably less than average. A standard
is necessary to classify these as "fires" or "misfires". The
enlargement of the hole into which the acceptor charge was
loaded was used as such a criterion. The enlargement associa-
tion with complete full rate detonation was determined by
firing a few shots at zero gap. The hole size was measured
using the shanks of number size drills as plug gages. The
largest size drill shank which would enter each of three
acceptor bodies, which had been fired at zero gap, was used
as a criterion of detonation for that particular type of
acceptor. The measurements were made at the end opposite to
that from which the acceptor had been fired since the other
end was distorted by the action of the donor. This standard
may be somewhat arbitrary, but experience indicates that the
choice of a standard should have relatively little influence
on the estimated critical points, since most acceptor bodies
show quite unmistakable evidence of either failure or detona-
tion. In some of the larger sizes a conical slug of metal
is spalled from the end of the acceptor body when detonation
occurs. In such cases, this type of fragmentation was used as
a criterion of detonation.

## Nonexplosive Components

8.   The donor and acceptor charges are loaded into heavy walled cylinders as shown on Plates 3 and 4. The donor is merely a cylinder with a hole of the desired column diameter and a counterbore to take the initiator (Plate 3). Brass was chosen because of its machining properties. The outer contours of the acceptor (Plate 4) were so designed to facilitate holding and locating. Copper was chosen because its properties should be more uniform than those of alloys as it is a pure metal.

## Explosive Materials, Preparation and Loading.

9.   Most of the explosives were used as received without preparation or modification except for drying where necessary. Relatively early in the investigation, it was found that the sensitivity of tetryl was strongly affected by particle size distribution and perhaps other factors. For this reason, all of the tetryl used was from the same two lots (whichwere compared and found indistinguishable). A through 35 on 45 U. S. Standard sieve cut of this tetryl was used. All explosives used for flash charges were ground in a small ball mill (reference (c)).

10.   Both donor and acceptor charges were loaded with the mating faces down on flat anvils so that the charges came flush with these ends. Thus, in the experiments, it could be assumed that if the containers were in surface contact the charges were in similar contact. Except where the effects of varying density were under consideration, all explosives in acceptors and the main columns of the donors were loaded at 10,000 pounds per square inch. The flash charges of the initiators were loaded at 4,000 pounds per square inch.

11.   In some of the early experiments, lead styphnate was used as a flash charge. It was observed that, when lead styphnate flash charges were used, enough time elapsed between the firing of the flash charge and the detonation of the donor charge for the initiator plug to be forced out of place in some cases. The resulting forward movement of the donor reduced the gap by an undetermined movement. Itwas determined that with lead azide flash charges this time was too short for appreciable movement to occur. For this reason lead azide flash charges were used in all experiments reported herein.

## Apparatus

12.   Tests of the kind described above required rather precise location of the acceptor with respect to the donor. The large number of firings required puts a premium on convenience. A scrapped lathe was adapted for this purpose. In a typical test the acceptor was mounted in the chuck and the donor in a fixture which was mounted on the tool rest. The donor is brought to a position such that it is concentric and in surface contact

with the acceptor. Its displacement from this position can be
accurately adjusted by means of the compound of the lathe.
Plate 5 shows the apparatus with donor and acceptor containers
in place. (Note the cushioned chuck jaws and the rotatable
donor fixture.) The lathe is shielded with armor plate
(Plate 6), and the doors of the shield are fitted with safety
interlock switches which disconnect the firing line when the
doors are open. The initiators are fired by the discharge of
a 50 microfarad paper condenser charged to 135 volts.

RESULTS AND DISCUSSIONS

13. Since it would be quite impractical to exactly duplicate
the arrangements used in these experiments in an ordnance
explosive system, the results of these experiments are interest-
ing in that they indicate trends rather than as absolute
numbers. For this reason the data are given, with a few
exceptions, in the form of curves relating the variables.
Most of the results are indicated on Plates 7 through 18.

Diameter Effects

14. On Plate 7 are plotted data obtained with various diameters
of donors and acceptors. All donors in this test were approxi-
mately 1/2 inch long columns of lead azide loaded at 10,000 psi.
As might be expected, the most notable trend is the direct
relationship between donor diameter and gap. The relationship
between acceptor diameter and gap is more complicated. Un-
fortunately, the range covered is too limited to give very
complete curves for any of the donor diameters used, but it
is apparent that each curve reaches a maximum at a point where
the acceptor diameter is somewhat smaller than that of the
donor. This phenomenon can quite readily be explained in terms
of radial losses. The radial losses of small column to the
surrounding material are larger in proportion to the chemical
potential energy available, so a smaller column must be more
vigourously initiated than a larger column. On the other hand,
if an impinging shock front strikes only a small fraction of
the face of an explosive column initiating detonation of the
affected area only, the radial losses to the surrounding
explosive will be greater than they would be to a denser
confining medium such as steel. As can be seen from Plate 12,
these relationships are affected by variations of other condi-
tions such as the loading density of both donor and acceptor.
An attempt was made to reduce the results of this particular
set of experiments to a useful analytical form. Plates 8, 9,
and 10 are various non-dimensional and semi-nondimensional
plots from which it was hoped to obtain some hint of a
systematic relationship. Plate 9 gives indication of such
a relationship. A slight modification of the coordinates
of Plate 9 gives Plate 10 on which all of the experimental

*detonators*

points fall reasonably close to a single curve. The curve
which best fits these points is, however, a cubic and the
substitution of the coordinate in the equation gives an
expression so complex that it is difficult to imagine a use
for it.

15. Curve number (1) on Plate 11 shows the relationship
between column length and critical axial air gap. It will
be noted that even when the length diameter ratio is as
large as 6, additional increments of column length are accom-
panied by increases in critical gap. Curve number (2)
indicates that, in the range covered, a given increase in
explosive weight is more effective when it is added by in-
creasing the diameter than when it is added by increasing
the length. To put it another way, the optimum length-
diameter ratio from the point of view of initiating efficiency
is apparently considerably below the 2 to 4 which is the most
common **practice in Navy detonators. This** type of efficiency,
however, is not necessarily the controlling factor in explosive
train design. For example, where a shutter mechanism is to
used as a safety device, less movement is probably necessary
for a given degree of safety with a long, slender detonator
than with a shorter, stouter detonator of the same initiating
effectiveness. The curves on Plate 11, as noted, are for lead
azide donors and tetryl acceptors. It is quite probable that
the optimum length-diameter ratio for other primary explosives,
such as mercury fulminate, which are not as quickly detonated
as lead azide is somewhat larger than that for lead azide.

Density Effects.

16. The sensitivity of explosives might be expected to increase
with percentage voids for two reasons:

   (a)  As the voids in an explosive increase, a shock of a
        given pressure can do more work per unit mass in
        compressing the material, thus raising it to a higher
        average temperature.
   (b)  The increasing inhomogeneity of the materials tends
        to increase the nonuniformity of heat distribution
        with the result that the hottest areas may be well
        above the average temperature.

17. This latter effect has two opposing results; the higher
temperature in some spots improves the probability of initia-
tion, while the lower temperature at other points increases
the time required for complete reaction (lengthening the reaction
zone), allowing more time for radial losses. The first effect,
while quite applicable when the initiating shock is transmitted
to the explosive through air or some other gas, becomes much
more complicated when the shock is transmitted to the explosive
from a less compressible material, in which case the intensity

of the transmitted shock depends upon the matching of acoustic impedances of the transmitting medium and the explosive. With so many variables involved, the relation between acceptor density and the probability of transmission of detonation is quite complex. Unfortunately, experimental data are available for only a few of the many possible combinations of the variables involved. On Plates 12 and 13 are plotted critical gaps obtained with various combinations of two donor diameters, two acceptor diameters and four densities of each charge. It will be noted that the gaps tend to increase with increasing donor density and to decrease with increasing acceptor density.

18. The experiment discussed in reference (a) indicates that the maximum sensitivity as measured by the thickness of a steel barrier through which a tetryl lead could be initiated by means of a certain British type of detonator reached a maximum when the density of the tetryl was about 1.35 grams per cubic centimeter. When copper was substituted for the steel or when air gap was introduced between the detonator and the degrading discs, this optimum density apparently increased, in many tests, to the highest density used (1.65).

19. Figure 14, which is taken from reference (d), shows the effect of density on the initiation sensitivity of several explosives as measured by the booster sensitivity tests described in reference (d). It will be noted that although the sensitivity of tetryl and TNT increases with percentage voids, that of Pentolite and Composition A is nearly independent of density. This may be because each of the last two explosives is a mixture of a sensitive high melting point material with a lower melting, less sensitive material. The most probable form that they would take would be particles with sensitive cores and insensitive surfaces. Thus the high temperature areas resulting from the inhomogeneity of the less dense charges are at the less sensitive parts of the explosive grains.

Confining Media

20. Experiments with varying confining media have been limited in scope up to now. One series was run using 0"100 diameter donors and acceptors of lead azide and tetryl, respectively, both loaded at 10,000 psi. The donor container, as usual, was of brass but the acceptor charges were loaded into copper, lead, aluminum and steel. The results are given below:

| Confining Medium (Acceptor) | Critical (50%) gap (Inches) | Acoustic (Shock) Impedance (Millions of gm/cm²) |
|---|---|---|
| Steel | 160 | 41 |
| Copper | 84 | 47.7 |
| Lead | 79 | 31 - 34.1 |
| Aluminum | 43 | 19.3 - 21.2 |

The acoustic impedances given were obtained from data (as yet unpublished) from measurements of shock velocities in metals close to detonating explosives. In general, the velocities are higher than sound velocities in the same materials. It will be noted that the gaps fall in the same general order as the impedances except in the case of steel. It might be postulated that the critical shock pressures lies within the strength of the steel yet well beyond that of the other materials so that the confining action of the steel is by a different mechanism than the other materials which confine the detonation only by virtue of their inertias.

21. On Plate 15, critical gaps obtained using various high explosives as acceptors are plotted against the drop sensitivity of the same explosives. It will be noted that the initiation sensitivity of the various explosives is in as good agreement with the impact sensitivity as can be expected with sensitivity tests. It would seem that the dream of discovering an explosive which is sensitive to initiation by means of another explosive yet mechanically insensitive will probably remain a dream. On Plate 15 the larger gaps obtained with mercury fulminate donors than with lead azide is mainly due to the higher loading density of the fulminate (both materials were pressed at 10,000 psi which gives a density of the order of 3 grams per cubic centimeter for lead azide and a density of the order of 3.6 grams per cubic centimeter for mercury fulminate) (reference (e)).

Transverse Displacement

22. A series of experiments was made in which the critical transverse displacement was determined for propagation between lead azide and mercury fulminate donors and acceptors of various high explosives. Plate 16 is a diagram of the test arrangement. On Plate 17 these data are plotted against the axial gaps obtained with the same combinations of explosives. The "s" shape of the curves is quite apparently related to the point at which the expanded hole in which the donor charge had been loaded is tangent to the unexploded acceptor, as shown on the sketch at the bottom of Plate 17. Evidently the initiation of some explosives, including tetryl, is quite probable when the holes overlap and quite improbable when they do not. This suggests that the initiation of these and less sensitive explosives is accomplished primarily by the hot highly compressed gases. For more sensitive materials such as RDX and PETN the metal borne shock is apparently an important mechanism. Some of the PETN and RDX acceptors were initiated in the interior as evidenced by the way in which the container was deformed, Plate 18. These data all were obtained using explosives loaded at 10,000 psi in #150 diameter holes. Experiments with other sizes and loading pressures are projected.

23. The specific conclusions which can be drawn from these experiments are discussed above and summarized in the abstract. In general it can be concluded that the field covered by these experiments is quite complex not only because of the number of variables involved, but because the relationship between some of these variables and the probability of transmission is not simple. On the other hand, taken individually the trends indicated are in general quite reasonable. Many questions remain which may well be answered by further experiments of a similar nature.

R. H. Stresau, Jr.

L. E. Starr, Jr.

EP:RHSJr:LESJr:elk

AIR GAP

EXPLOSIVES
BEING
TESTED

DONOR

ACCEPTOR

PLATE 2

# EXPLOSIVES SENSITIVITY TEST
NAVORD-OSL-0349 (11-57)
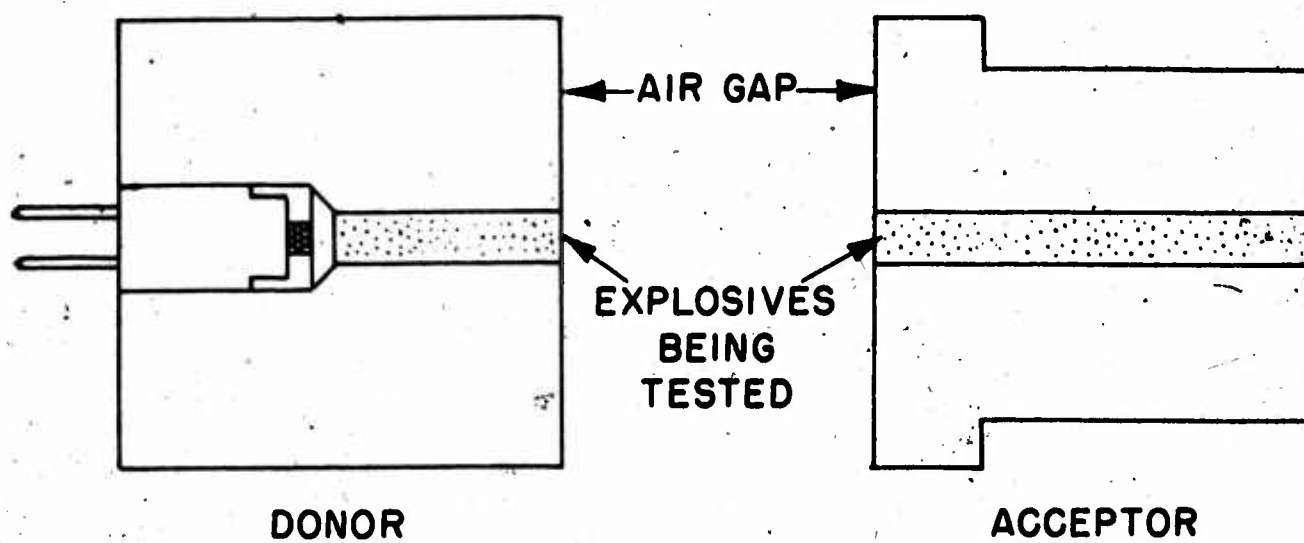
| DISTRICT WORK ORDER NUMBER | LOADING WORK ORDER NUMBER | BATCH NUMBERS |
| --- | --- | --- |
| FLASH CHARGE MATERIAL | POTENTIAL 135 | CAPACITANCE 50 µf |
| CURRENT | STEP SIZE Log 0.05 | DATE OF TEST |
| BRIDGE A42 | MILLED | |
| RESULTS MEAN 0.0255 | TESTED BY Starr | |
| BOMB SIZE 0.075 dia. Loading order (0.0063) | ACCEPTOR SIZE 0.150 dia. Loading order (0.0022) | |
| REMARKS | | |
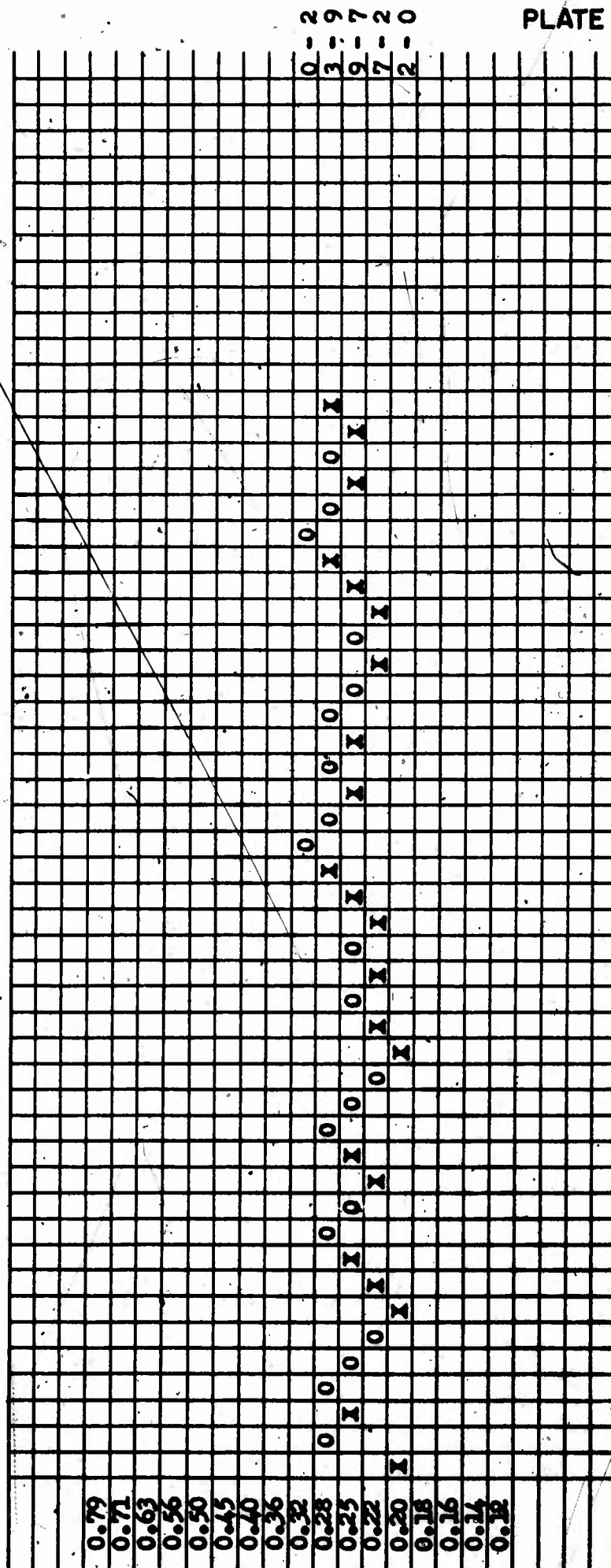


0.79
0.71
0.63
0.56
0.50
0.45
0.40
0.36
0.32
0.28
0.25
0.22
0.20
0.18
0.16
0.14
0.12

PLATE 3

SMOOTH FINISH

"Y" ±.010

.531 ±.005

1.00 STOCK

17/64 DRILL

"X" DIA. +.0005 -.0000
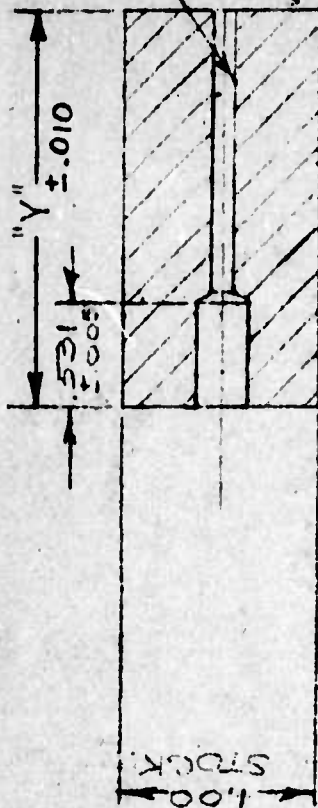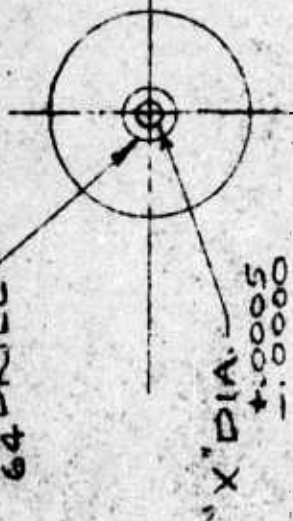
NOTE:
HOLES TO BE CONCENTRIC TO WITHIN ±.002

| PC.NO. | "X" | "Y" | PC.NO. | "X" | "Y" | PC.NO. | "X" | "Y" |
|---|---|---|---|---|---|---|---|---|
| 1 | .062 | 1.00 | 8 | .050 | 2.00 | 15 | .100 | 3.00 |
| 2 | .062 | 2.00 | 9 | .050 | 3.00 | 16 | .150 | 1.00 |
| 3 | .062 | 3.00 | 10 | .075 | 1.00 | 17 | .150 | 2.00 |
| 4 | .125 | 1.00 | 11 | .075 | 2.00 | 18 | .150 | 3.00 |
| 5 | .125 | 2.00 | 12 | .075 | 3.00 | 19 | .200 | 1.00 |
| 6 | .125 | 3.00 | 13 | .100 | 1.00 | 20 | .200 | 2.00 |
| 7 | .050 | 1.00 | 14 | .100 | 2.00 | 21 | .200 | 3.00 |

NOTE:
DO NOT REMOVE SHARP EDGES.

NOLM 10577

BUREAU OF ORDNANCE, NAVY DEPARTMENT
U.S. NAVAL ORDNANCE LABORATORY
WHITE OAK
SILVER SPRING 19, MARYLAND
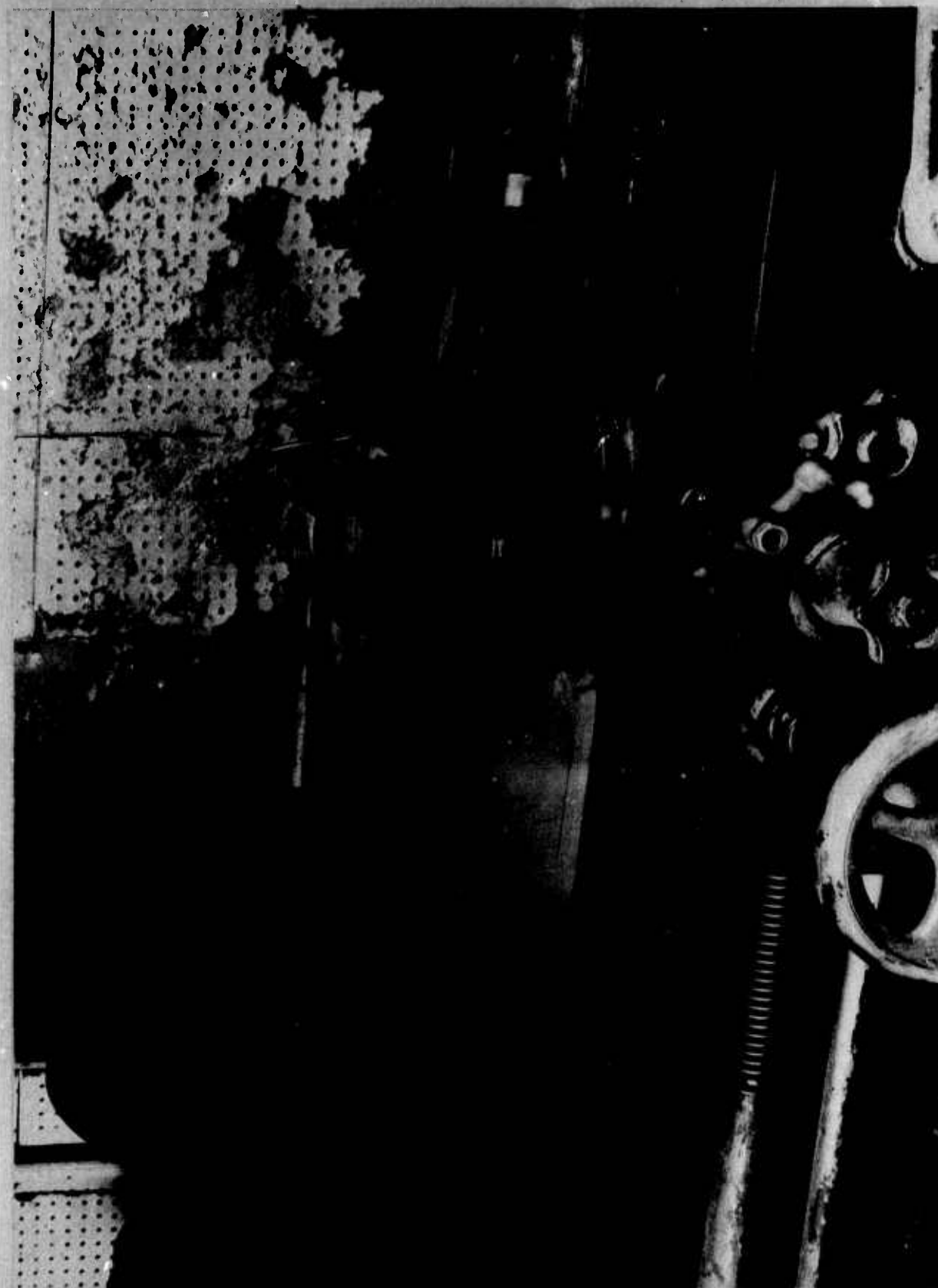194

BY DIRECTION OF THE CHIEF OF BUREAU

DONOR

MATERIAL BRASS, COMM.

CLASS

UNIT WT. JOB ORDER

SCALE 1/1

BUONE DRAWING NO.
NOL SK 80631

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UNLESS OTHERWISE SPECIFIED
REMOVE BURRS AND SHARP EDGES. DIMENSIONS ARE IN INCHES. TOLERANCES ON MACHINING DIMENSION.

DATE
APPROVED
CHECKED
DRAWN E.P. 12.14.45

LET. NUMBER DATE
REVISIONS

PLATE 4

NOL SK. 80642

"X" DIA
+.0005
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NOTE:
HOLES TO BE CONCENTRIC
TO WITHIN ±.002
DO NOT REMOVE SHARP EDGES.

SMOOTH FINISH

"Y" ±.010

.750 ±.010

1.000

STOCK
1.000

| PC.NO | "X" | "Y" |
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| 18 | .150 | 3.00 |
| 19 | .200 | 1.00 |
| 20 | .200 | 2.00 |
| 21 | .200 | 3.00 |

ACCEPTOR
FOR GAP TEST INITIATOR

MATERIAL COPPER

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DO NOT SCALE DRAWING

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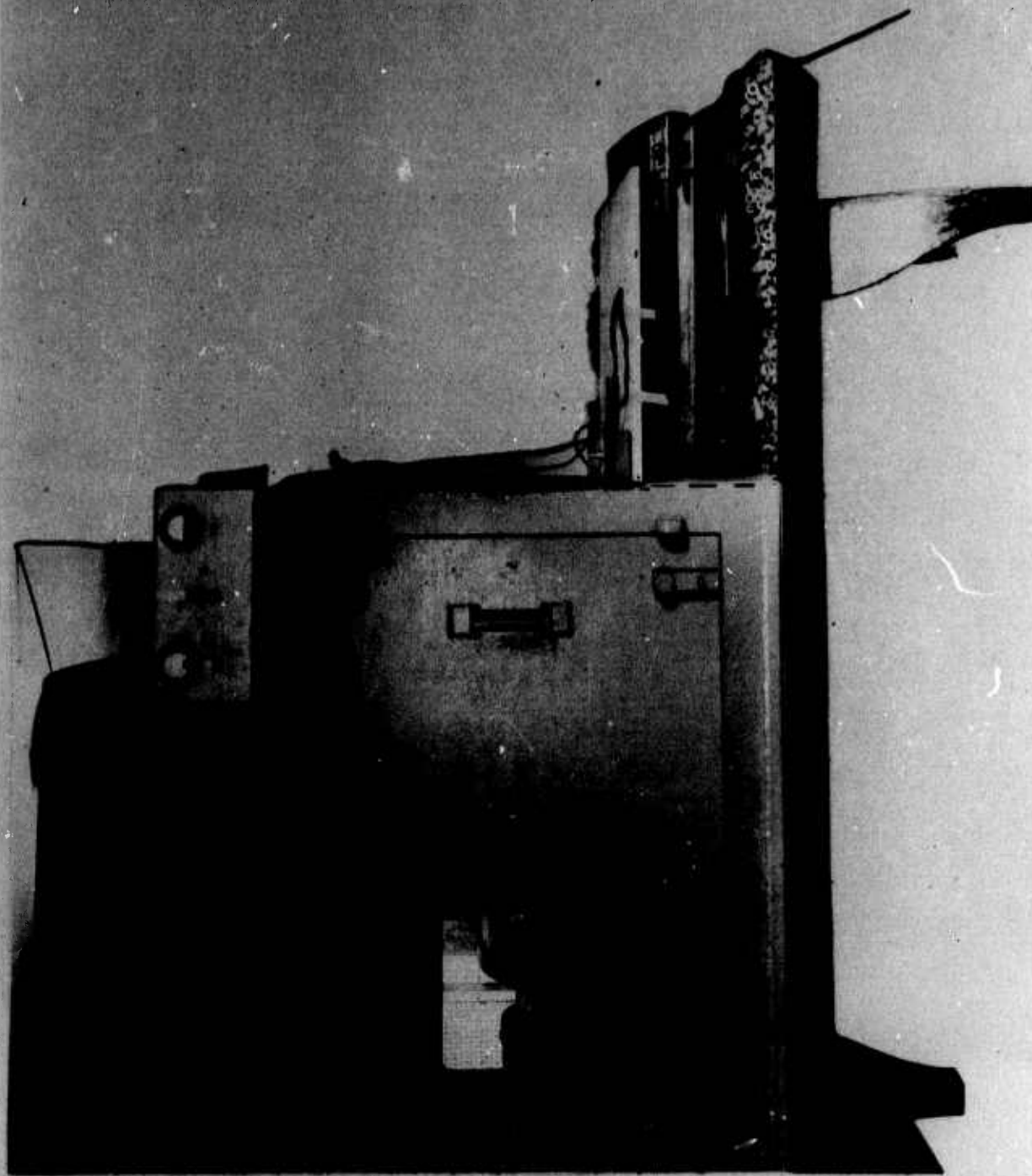
NOLM 10577   PLATE 4

PLATE 5

PLATE 6

CRITICAL GAP AS A FUNCTION OF COLUMN DIAMETER

PLATE 8
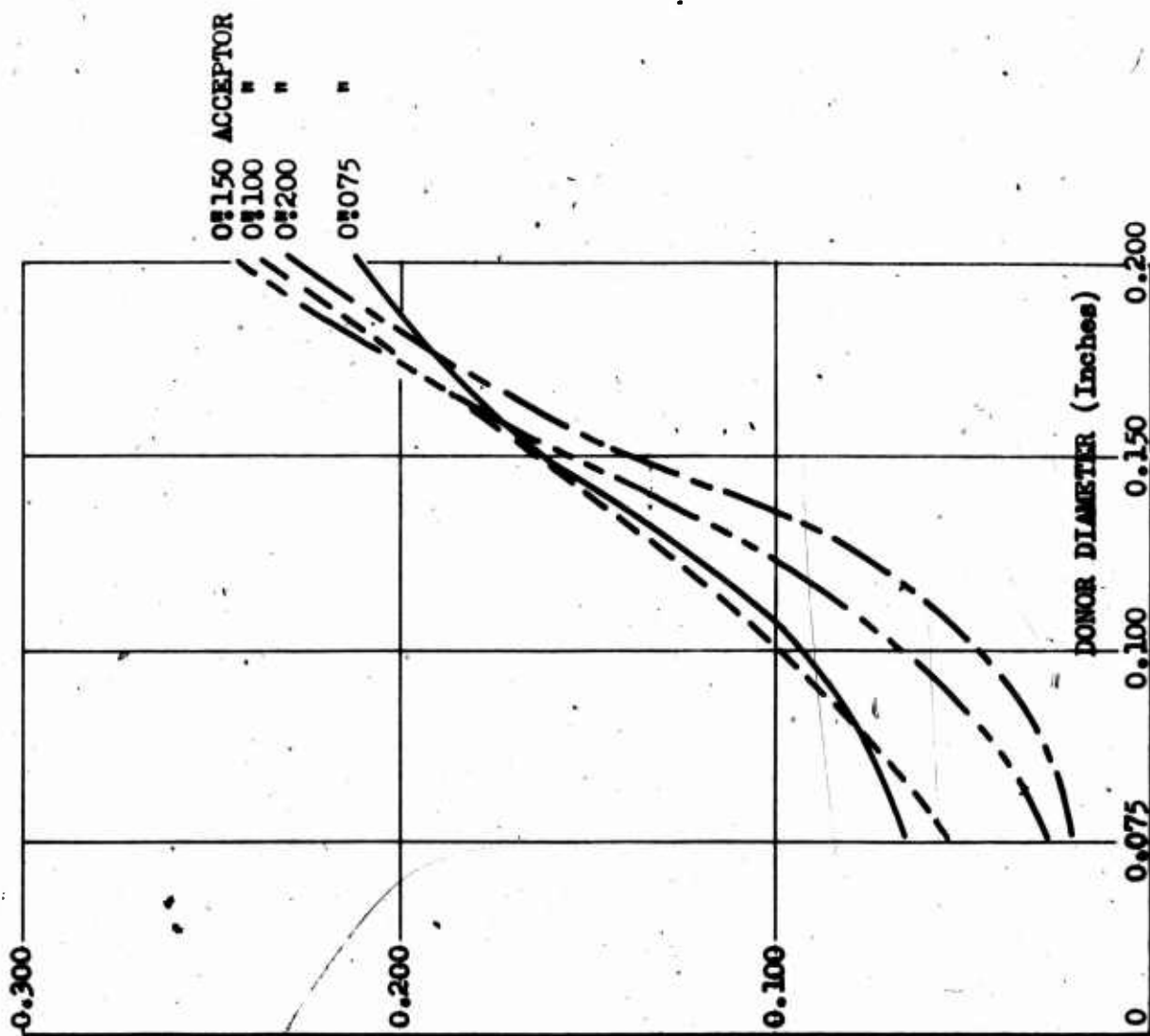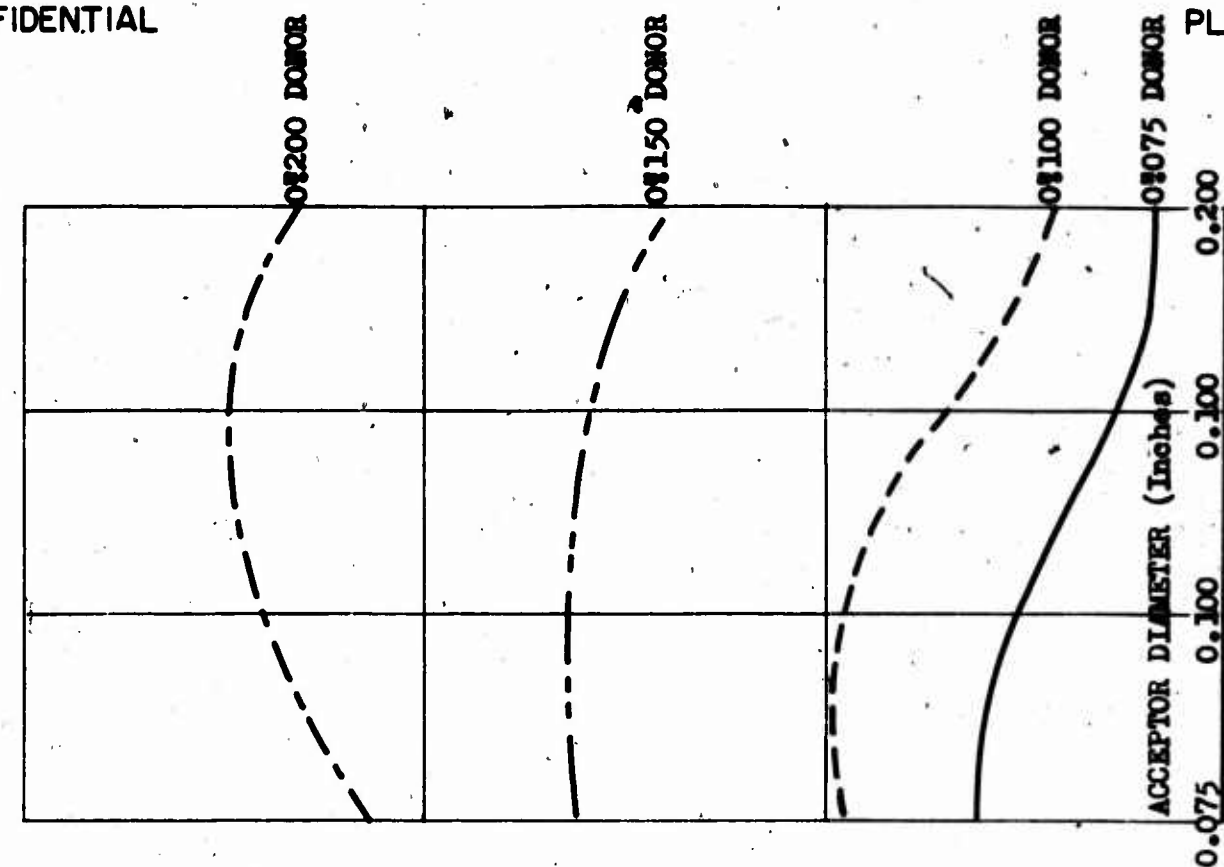
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HIGHLY CONFINED LEAD AZIDE DONORS AND HIGHLY CONFINED TETRYL ACCEPTORS
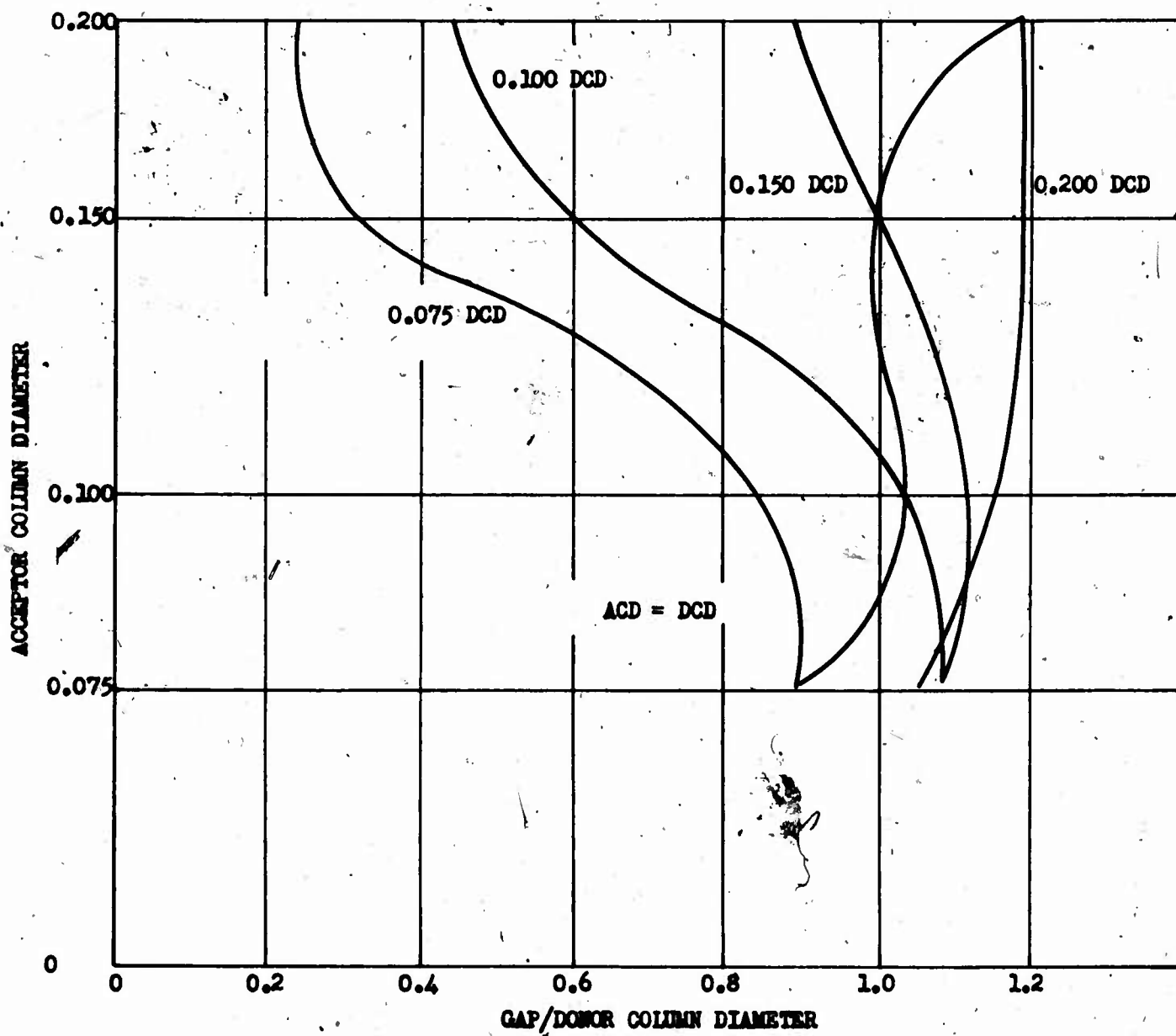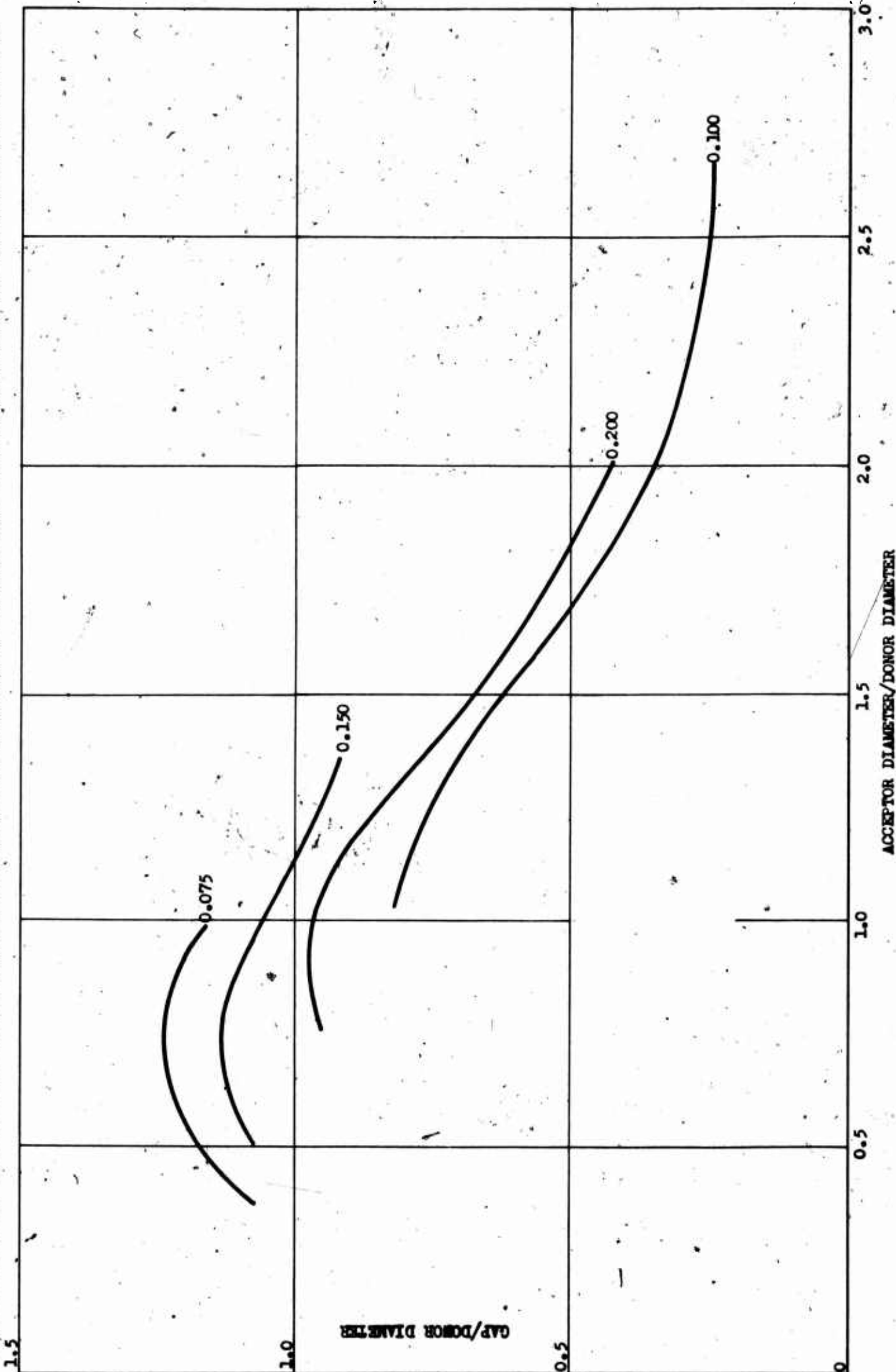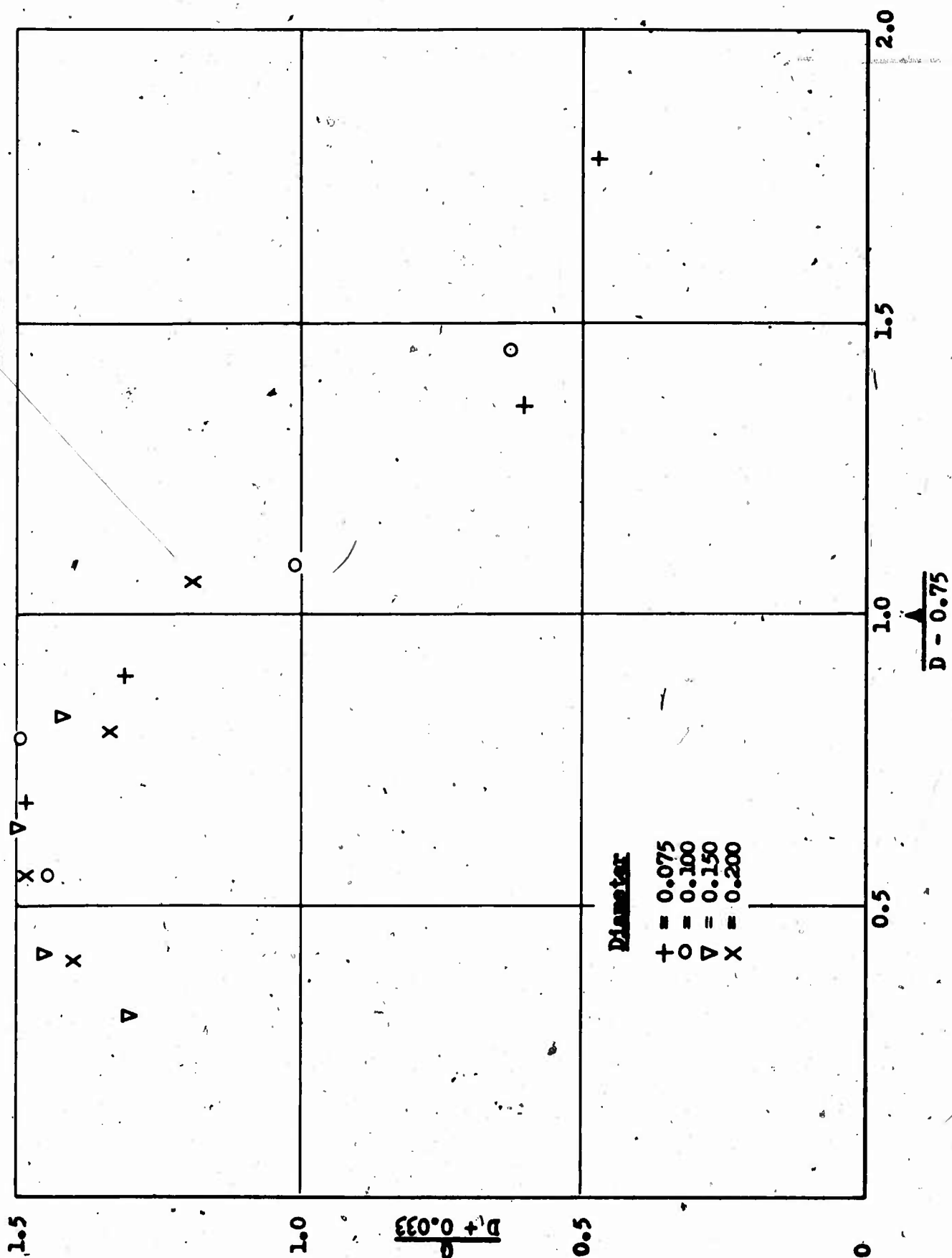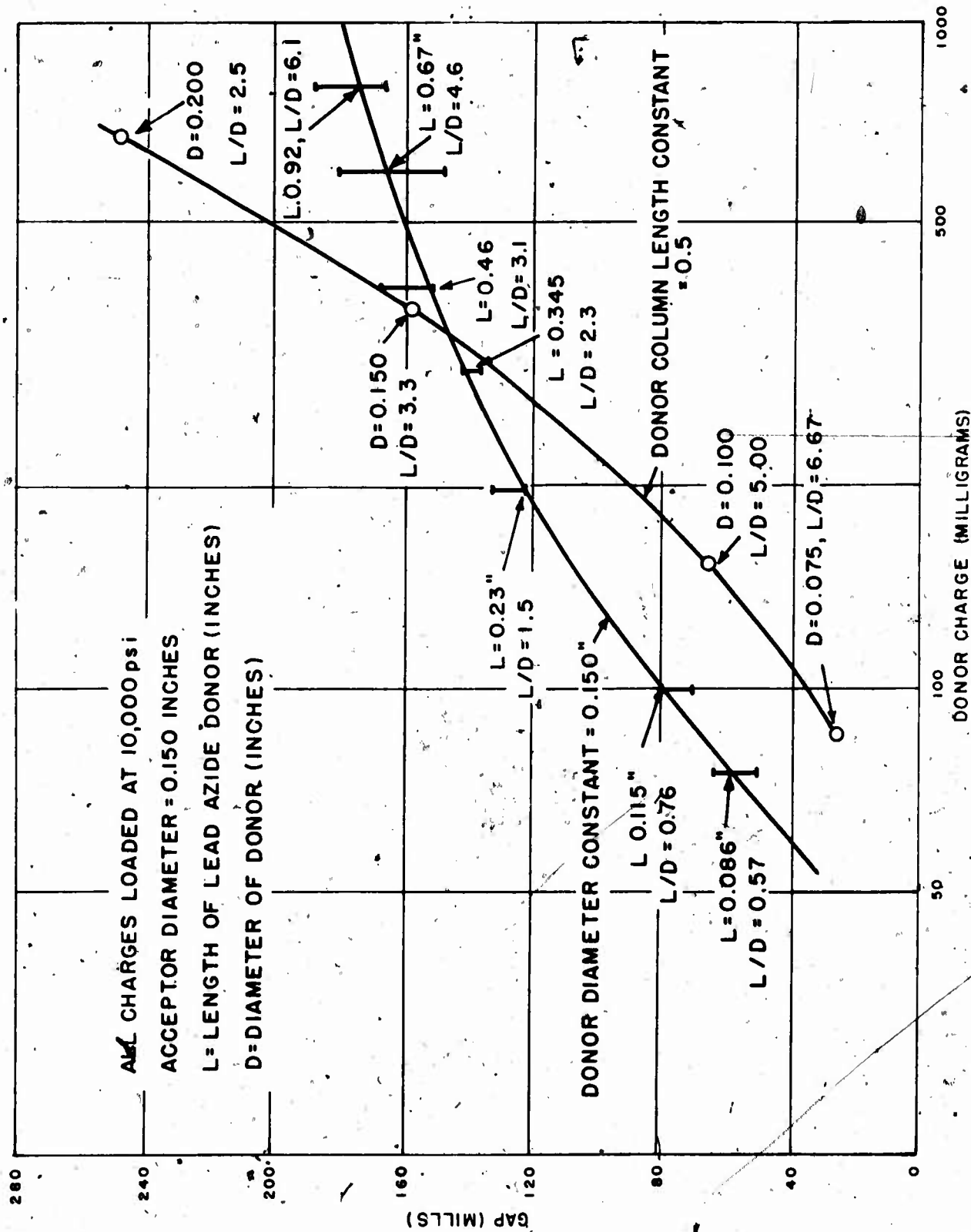
GAP AS A FUNCTION OF COLUMN DIAMETER FOR CRITICAL PROPAGATION BETWEEN HIGHLY CONFINED LEAD AZIDE DONORS AND HIGHLY CONFINED TETRYL ACCEPTORS

GAP AS A FUNCTION OF COLUMN DIAMETER FOR THE CRITICAL PROPAGATION
BETWEEN HIGHLY CONFINED LEAD AZIDE AND HIGHLY CONFINED TETRYL

PLATE 11

## CRITICAL AXIAL AIR GAPS ACROSS WHICH DETONATION IS TRANSMITTED BETWEEN LEAD AZIDE AND TETRYL

ALL CHARGES LOADED AT 10,000 psi

ACCEPTOR DIAMETER = 0.150 INCHES

L = LENGTH OF LEAD AZIDE DONOR (INCHES)

D = DIAMETER OF DONOR (INCHES)

D = 0.200
L/D = 2.5

L 0.92, L/D = 6.1

L = 0.67"
L/D = 4.6

L = 0.46
L/D = 3.1

L = 0.345
L/D = 2.3

D = 0.150
L/D = 3.3

DONOR COLUMN LENGTH CONSTANT = 0.5

D = 0.100
L/D = 5.00

D = 0.075, L/D = 6.67

L = 0.23"
L/D = 1.5

DONOR DIAMETER CONSTANT = 0.150"

L 0.115"
L/D = 0.76

L = 0.086"
L/D = 0.57

DONOR CHARGE (MILLIGRAMS)

GAP (MILLS)

280

240

200

160

120

80

40

0

50

100

500

1000

PLATE 12



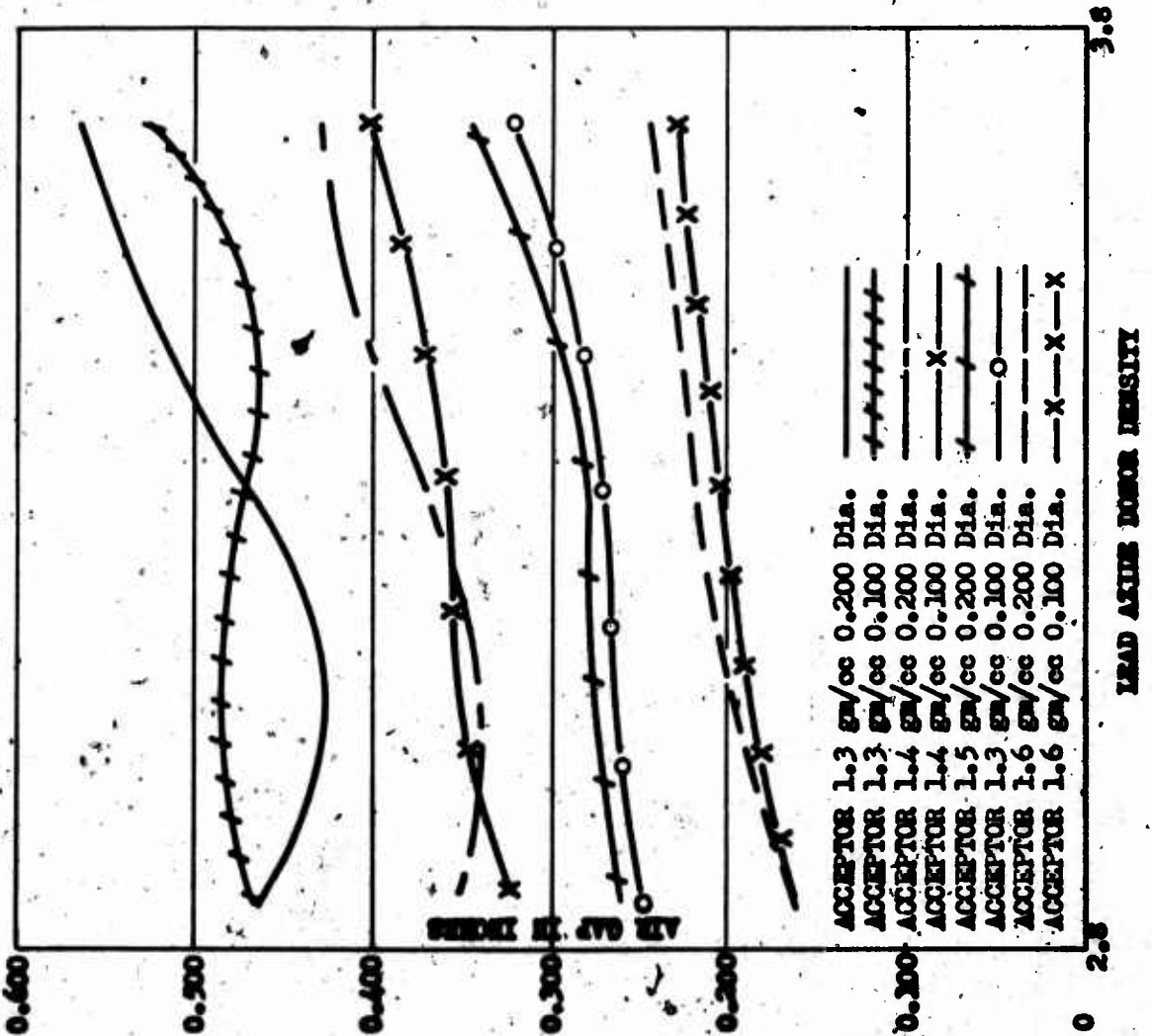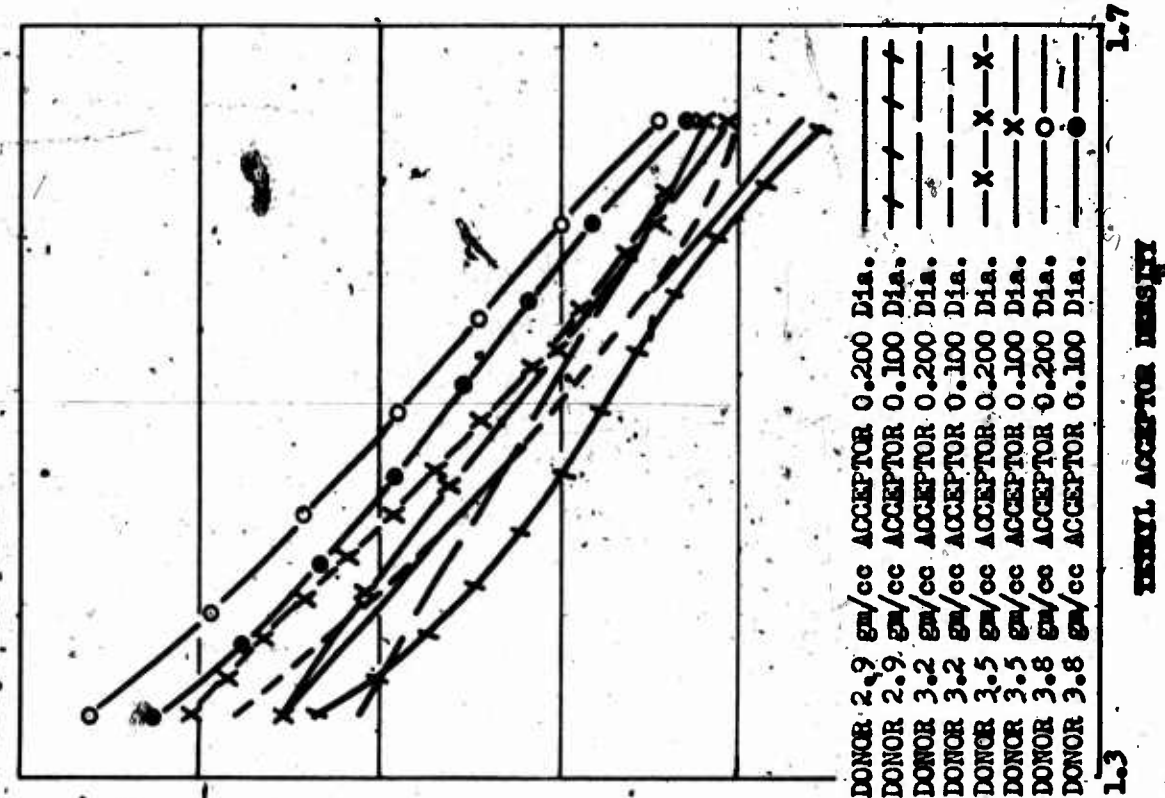CRITICAL GAP AS A FUNCTION OF DENSITY

0.100" Diameter Lead Azide Donors
0.100" and 0.200" Diameter Tetryl Acceptors
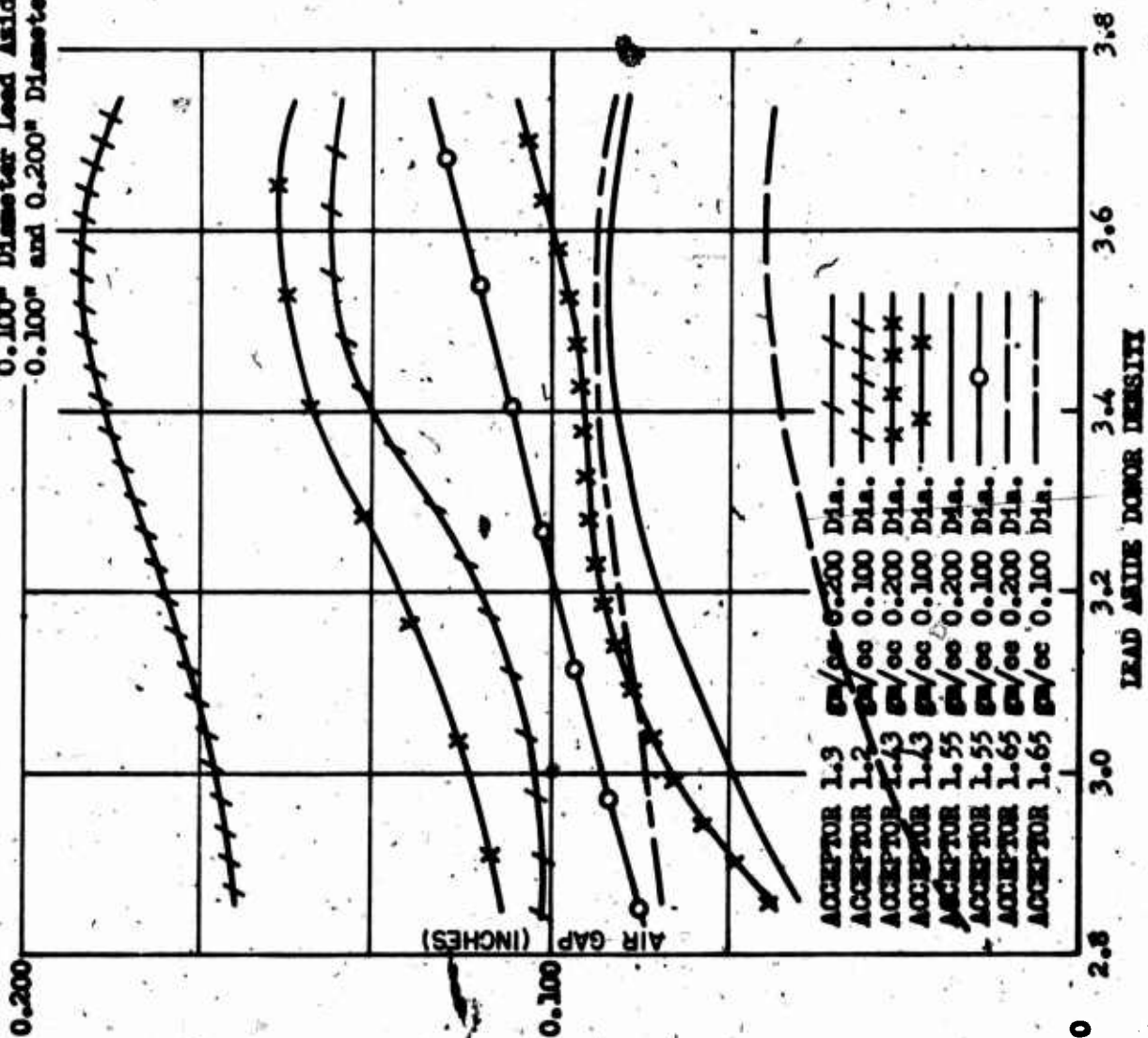
CRITICAL GAP AS A FUNCTION OF DENSITY

0.200" Dia. Lead Azide Donors
0.100" and 0.200" Dia. Tetryl Acceptors

RADIAL ACCEPTOR DENSITY

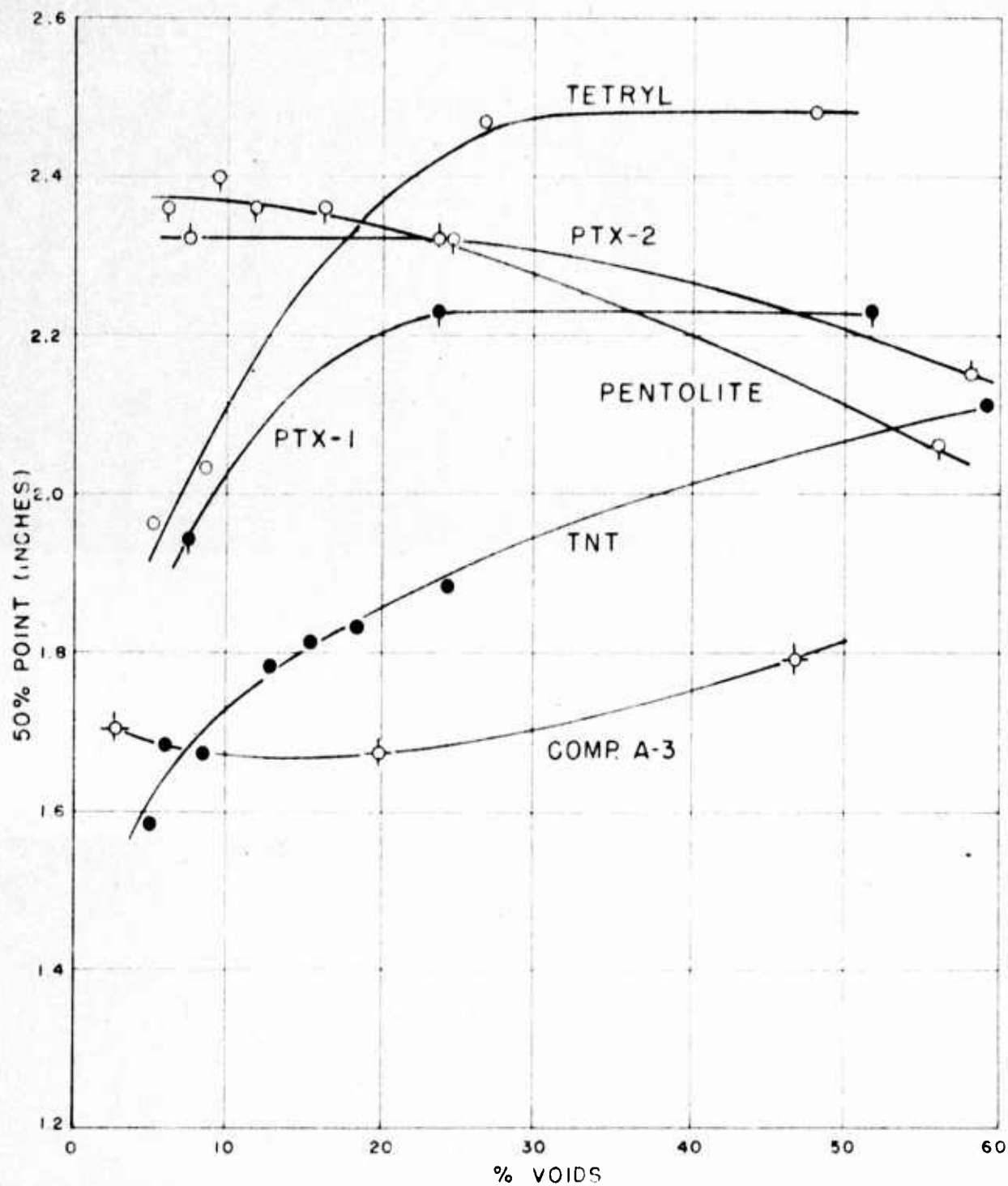DONOR 2.9 gm/cc ACCEPTOR 0.200 Dia.
DONOR 2.9 gm/cc ACCEPTOR 0.100 Dia.
DONOR 3.2 gm/cc ACCEPTOR 0.200 Dia.
DONOR 3.2 gm/cc ACCEPTOR 0.100 Dia.
DONOR 3.5 gm/cc ACCEPTOR 0.200 Dia.
DONOR 3.5 gm/cc ACCEPTOR 0.100 Dia.
DONOR 3.8 gm/cc ACCEPTOR 0.200 Dia.
DONOR 3.8 gm/cc ACCEPTOR 0.100 Dia.

LEAD AZIDE DONOR DENSITY

ACCEPTOR 1.3 gm/cc 0.200 Dia.
ACCEPTOR 1.3 gm/cc 0.100 Dia.
ACCEPTOR 1.4 gm/cc 0.200 Dia.
ACCEPTOR 1.4 gm/cc 0.100 Dia.
ACCEPTOR 1.5 gm/cc 0.200 Dia.
ACCEPTOR 1.3 gm/cc 0.100 Dia.
ACCEPTOR 1.6 gm/cc 0.200 Dia.
ACCEPTOR 1.6 gm/cc 0.100 Dia.
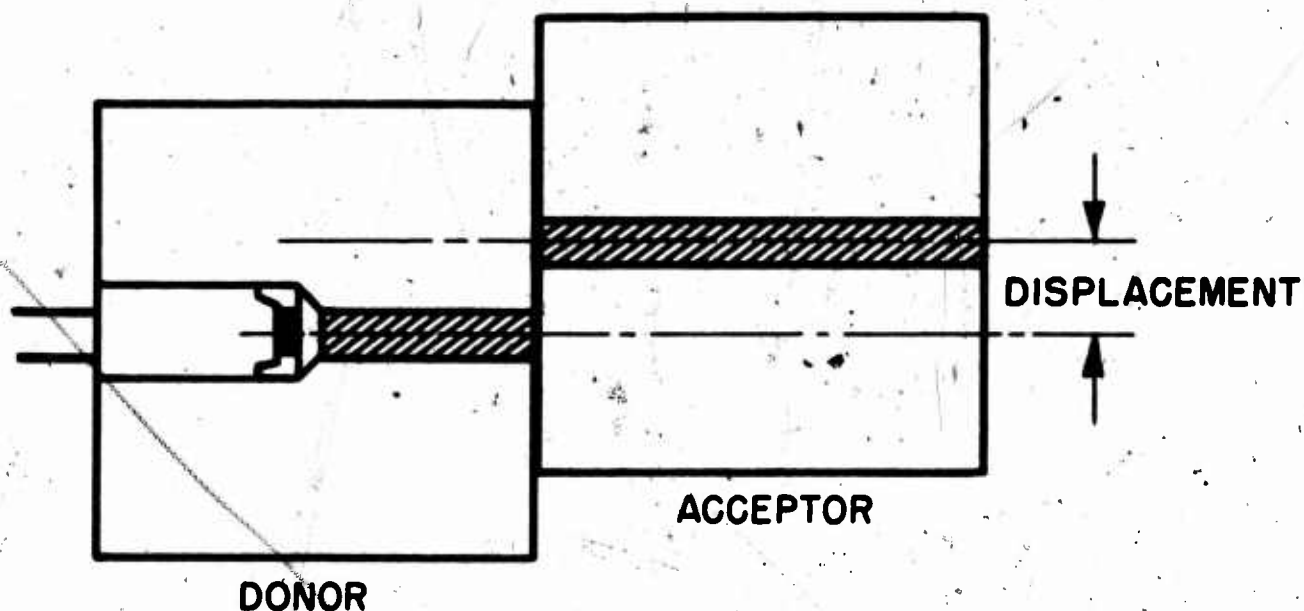
## 50% POINT vs % VOIDS

PLATE 15



MINIMUM PRIMING CHARGE AND GAP FOR CRITICAL PROPAGATION
VS
IMPACT SENSITIVITY

DONOR 0".150 DIAMETER x 0".500 LONG
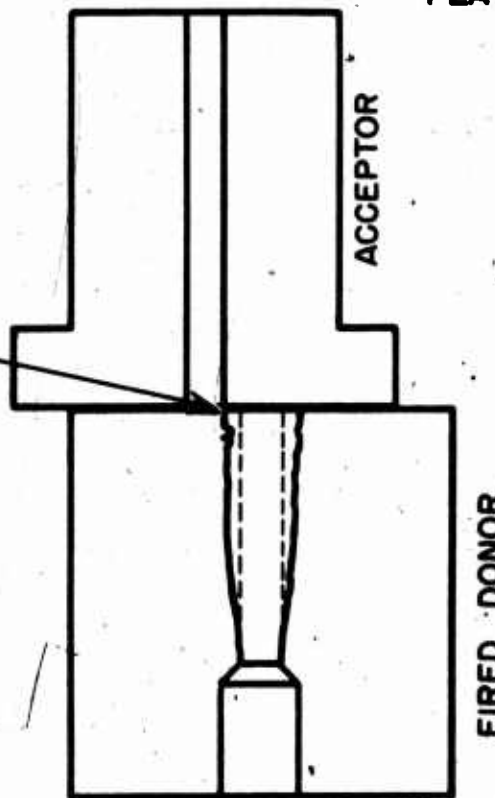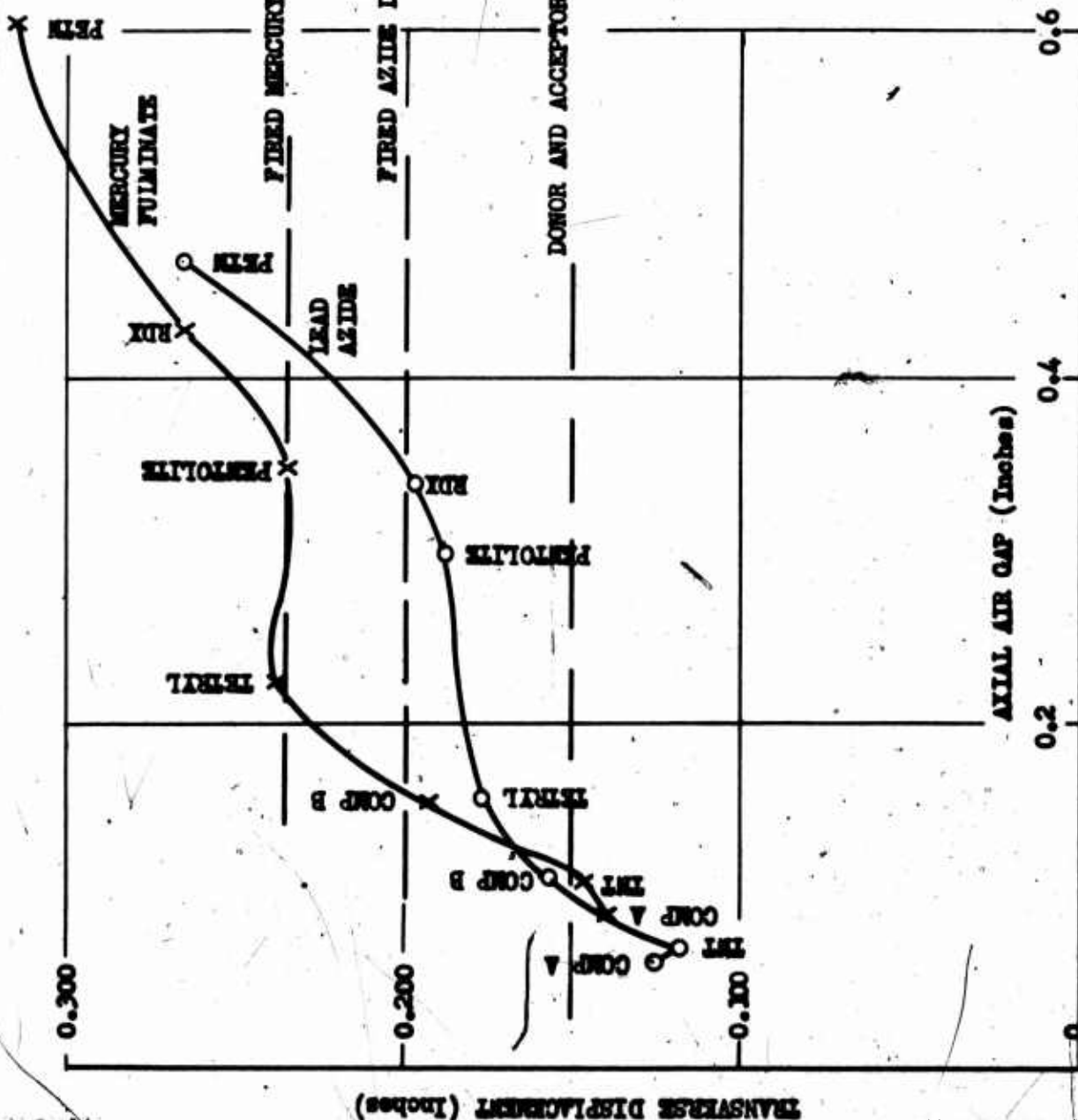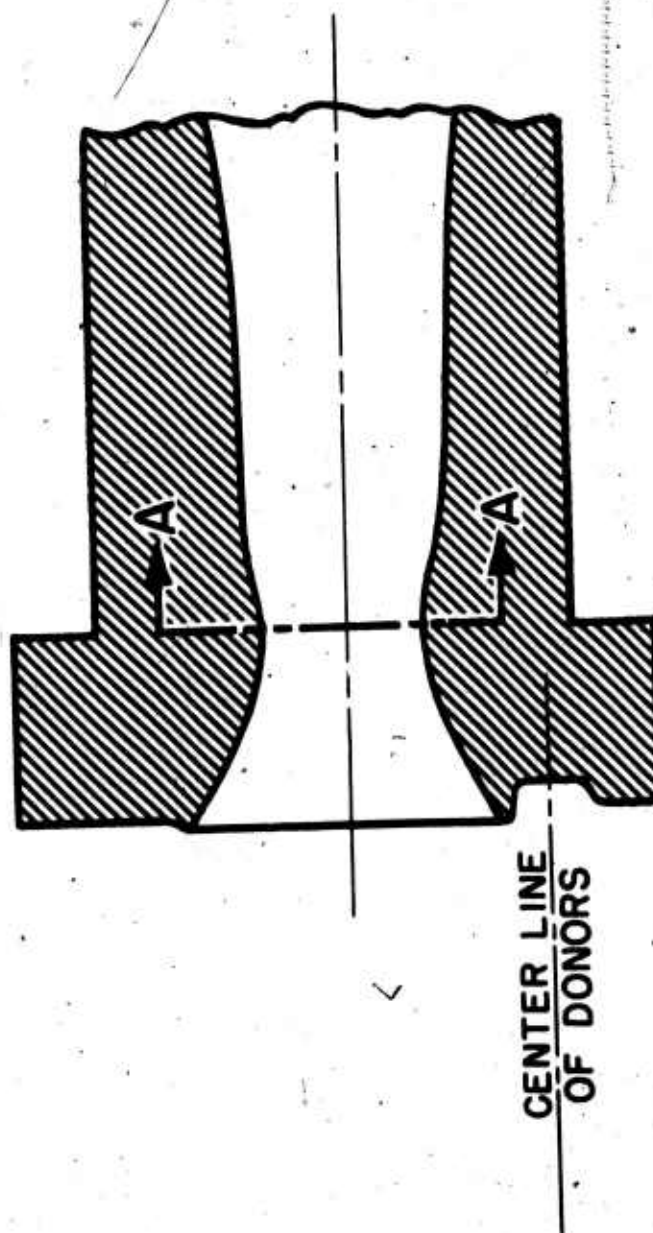ACCEPTOR 0".150 DIAMETER x 1".00 LONG

PLATE 16
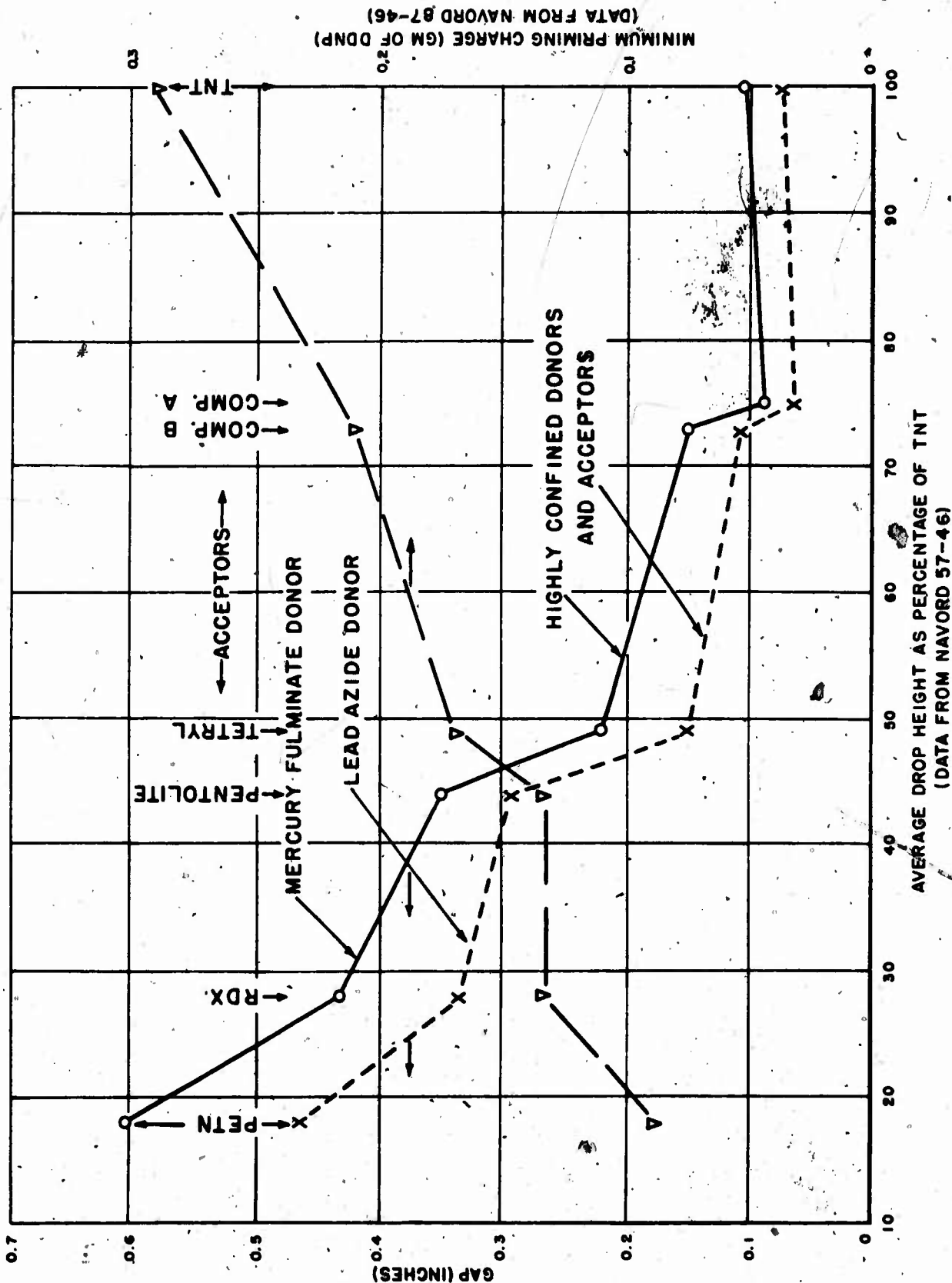


ARRANGEMENT OF DONOR AND ACCEPTOR
IN THE TRANSVERSE DISPLACEMENT TESTS

PLATE 17



INITIATION PROPERTIES OF THE EXPLOSIVES ACROSS TRANSVERSE DISPLACEMENT AND AXIAL AIR GAPS

LOADING PRESSURE: 10,000 psi
INCH COLUMN DIA: 0#150

PLATE 18



POINT OF INITIATION A A

CENTER LINE OF DONORS